Calibration Aspects of STAR experiment's Heavy Flavor Tracker (HFT)

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Abstract

The Heavy Flavor Tracker (HFT) is a new silicon detector in the STAR experiment at RHIC [1]. It consists of three subsystems and four layers of silicon detectors. The heart of the system is the two inner layers of PXL (pixel) detector. The PXL uses ultra thin sensors (50 μm) with ~20x20 microns active pixel MAPS (Monolithic Active Pixel Sensors) technology. The air-cooled, lightweight pixel detector is surrounded by two subsystems: the SSD (Silicon Strip Detector) and IST (Intermediate Silicon Tracker). These two layers of silicon help us interface and connect the PXL hits to the Time Projection Chamber (TPC) tracks. The full system is capable of a track pointing (DCA) resolution at the event vertex of about ~30 μm for 1 GeV/c pions. In Spring-2014 the HFT system had its first physics run with Au+Au collisions at 200 GeV. In this poster we report on track pointing resolution performance, and on calibrations efforts like masking and alignment.

The Physics concepts of Heavy Flavor Tracker

The goal of high-energy nuclear collisions at RHIC is to study nuclear matter at extremely high temperatures and energy densities. Under these extraordinary conditions, a new thermalized state of quark and gluons, called the Quark-Gluon Plasma (QGP), is expected to be created.

Heavy flavor quarks are considered to be a unique probes for QGP studies; however, their low production yield and short life-span (a picosecond or less) make them difficult to study in heavy-ion collisions that also produce large quantities of light flavor particles [1,2].

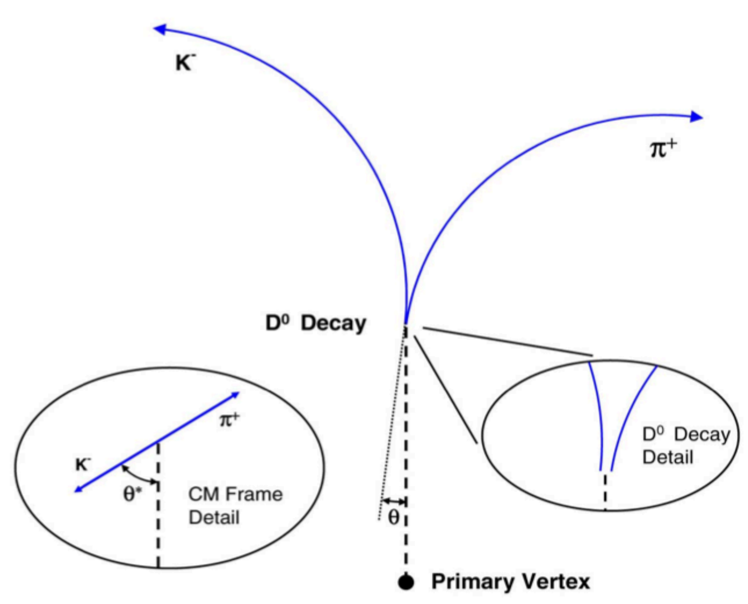


Figure 1: D^0 mason production and subsequent decay into K^- and π+

- HFT can be used to study and detect heavy flavor production by reconstruction of displaced decay vertices.
- It significantly reduces the combinational background with the help of its excellent track pointing resolution.

Examples of displaced decay vertices:

- $D^0 \rightarrow K^-\pi^+$ BR = 3.83 % $c\tau$ ~ 120 μm
- $\Lambda c^+ \rightarrow p K^- \pi^+$ BR = 5.0 % $c\tau$ ~ 60 μm
- B mesons → J/ψ + X or e + X $c\tau$ ~ 500 μm

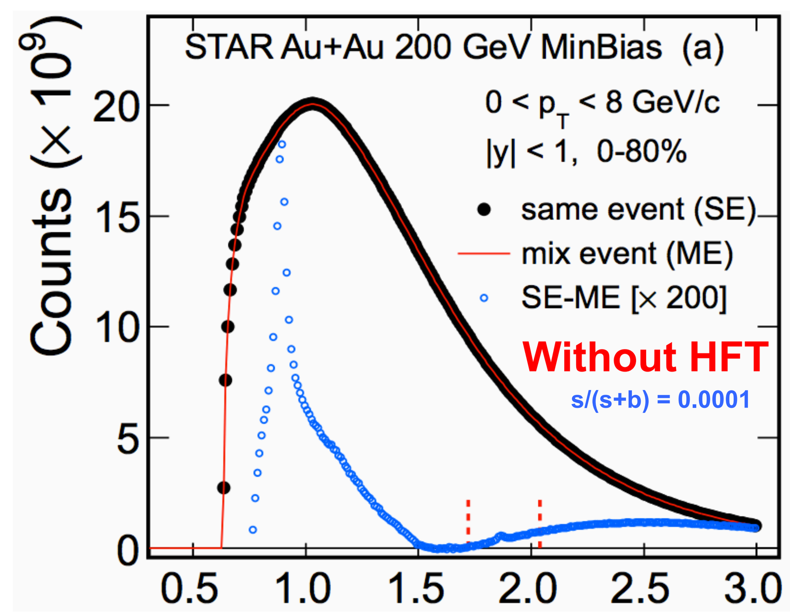


Figure 2: Inv. Mass distribution for all the combinations of kaon and pion candidates [3]

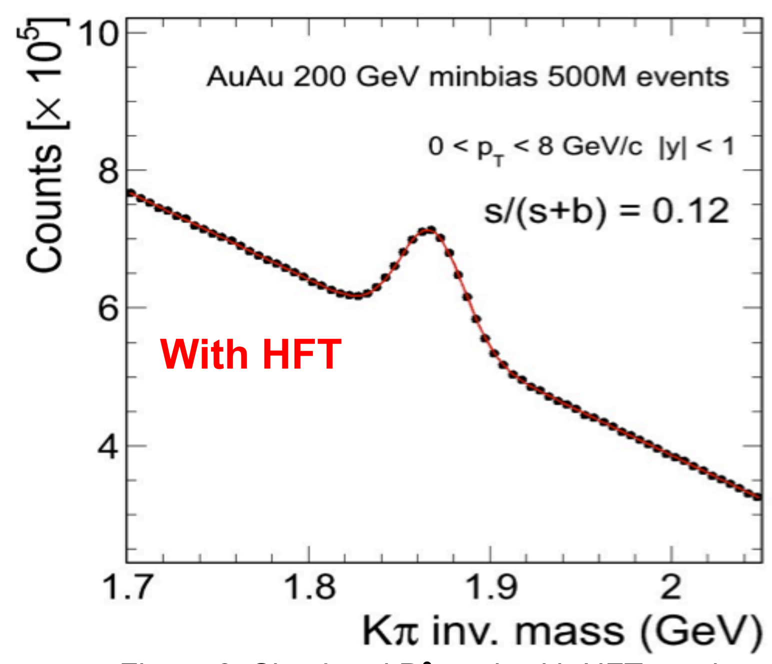
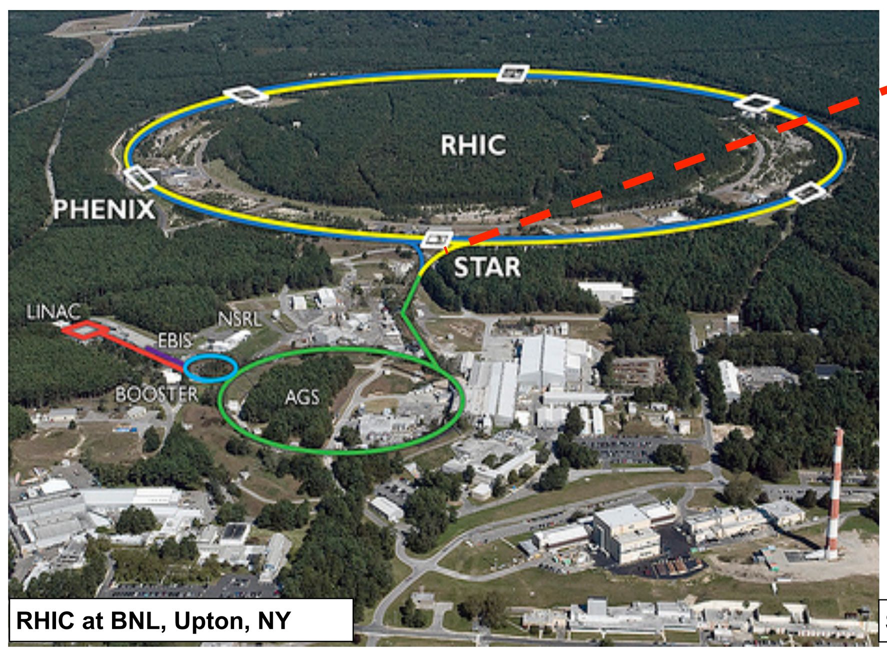
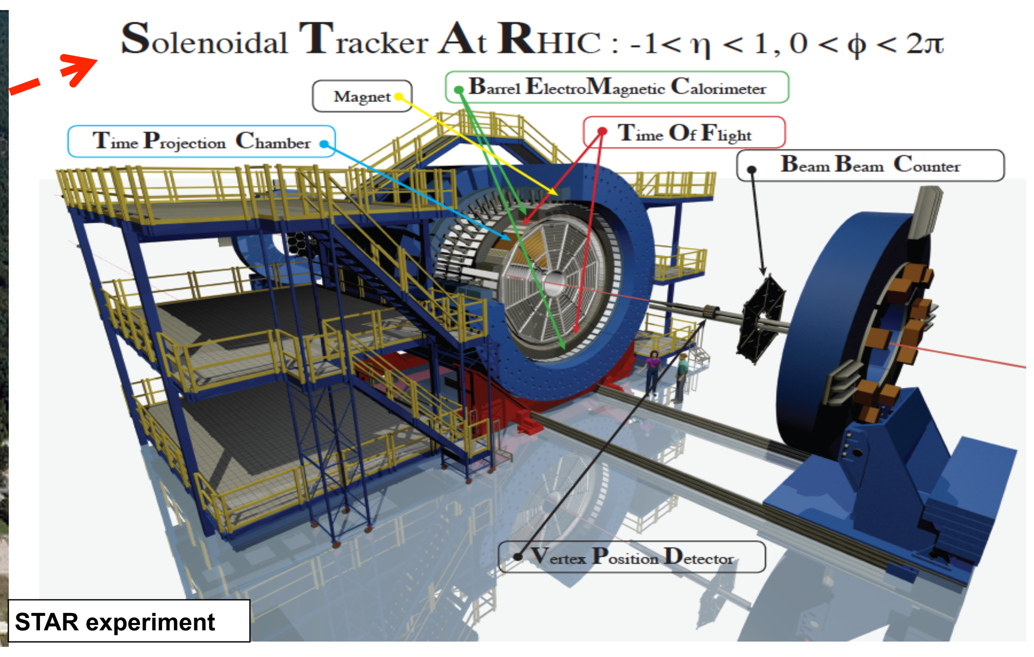


Figure 3: Simulated D^0 peak with HFT used

STAR Experiment at RHIC





Technical Design of HFT

To identify the mid rapidity Charm and Beauty mesons and baryons through direct reconstruction and measurement of the displaced vertex with high quality of pointing resolution, the STAR collaboration has installed the HFT detector. It contains the following three systems:

SSD-Silicon Strip Detector: A (refurbished) double sided silicon strip detector of one layer located 22 cm from the beam axis.

IST – Intermediate Silicon Tracker: A silicon pad detector (single sided) located at a radius of 14 cm. It is composed of 24 liquid cooled ladders equipped with 6 silicon strip-pad sensors. The main purpose of the IST and SSD is to connect the tracks from TPC to PXL detector (intermediate trackers).

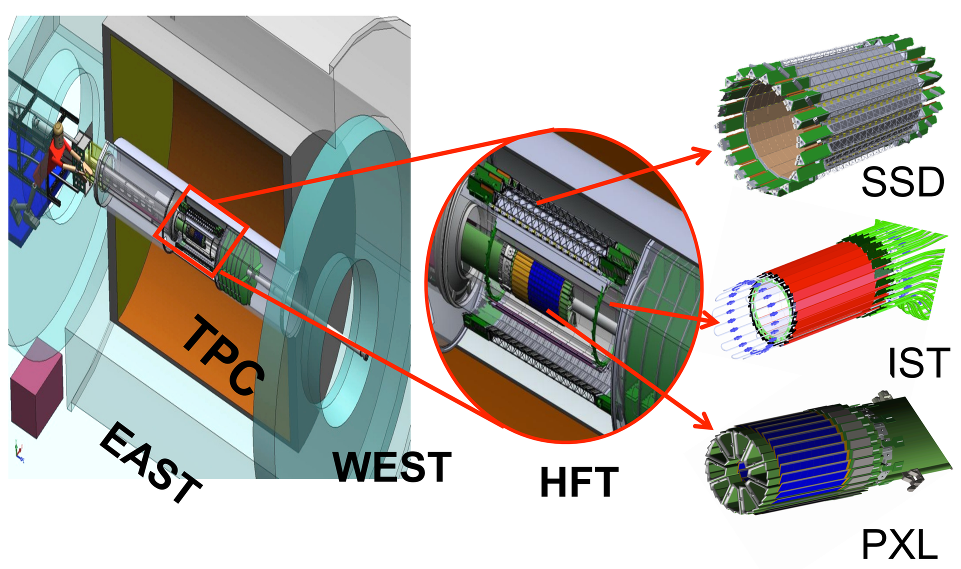


Figure 4: (left) HFT detector inside the STAR, (mid) HFT and (right) SSD, IST and PXL

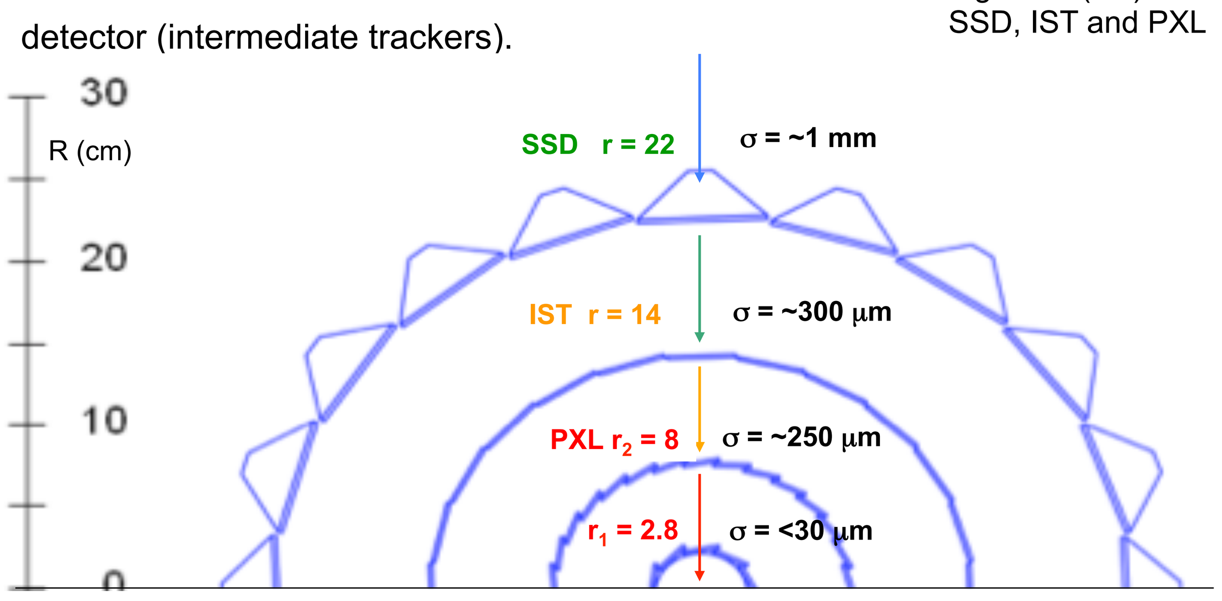


Figure 5: A schematic view of the HFT detector shows the radius of each detector with its resolution

PXL – Silicon Pixel Detector: The two inner layers at 2.8cm and 8cm from the beam axis consist of silicon pixel detector. They are based on the state-of-the art (MAPS) having pixel size 20 μm x 20 μm. The PXL detector defines the track pointing resolution and also determines the position of secondary decay vertices very precisely.

PXL Detector Masking

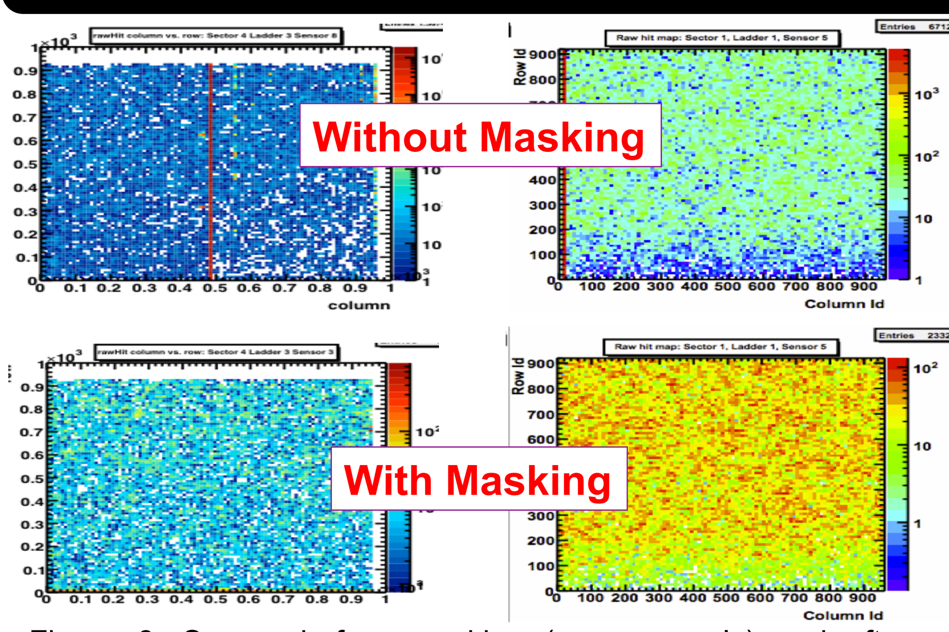


Figure 6: Sensor before masking (upper panels) and after masking (lower panels)

The goal of masking individual pixel is to remove noisy sensors and/or channels from the data stream. Masking tables for all physics obtained during the 2014 running were produced and uploaded to STAR database.

In Fig 6 the top two plots show the raw, unmasked hit map for two noisy sensors showing a cluster of hot columns. The two plots at the bottom are the same sensors after masking is applied. The distribution of raw hits is clearly more homogeneous and the scale is no longer dominated by the contribution of these hot channels [4].

Alignment of HFT

The procedures of alignment is to determine the in-situ position of the detector elements and correct the geometry tables used in local to global coordinates transformations. Self-aligning the PXL detector is the first step. Next is the alignment of both IST and SSD detectors to PXL. The final step is to place the four layers of the HFT within the TPC.

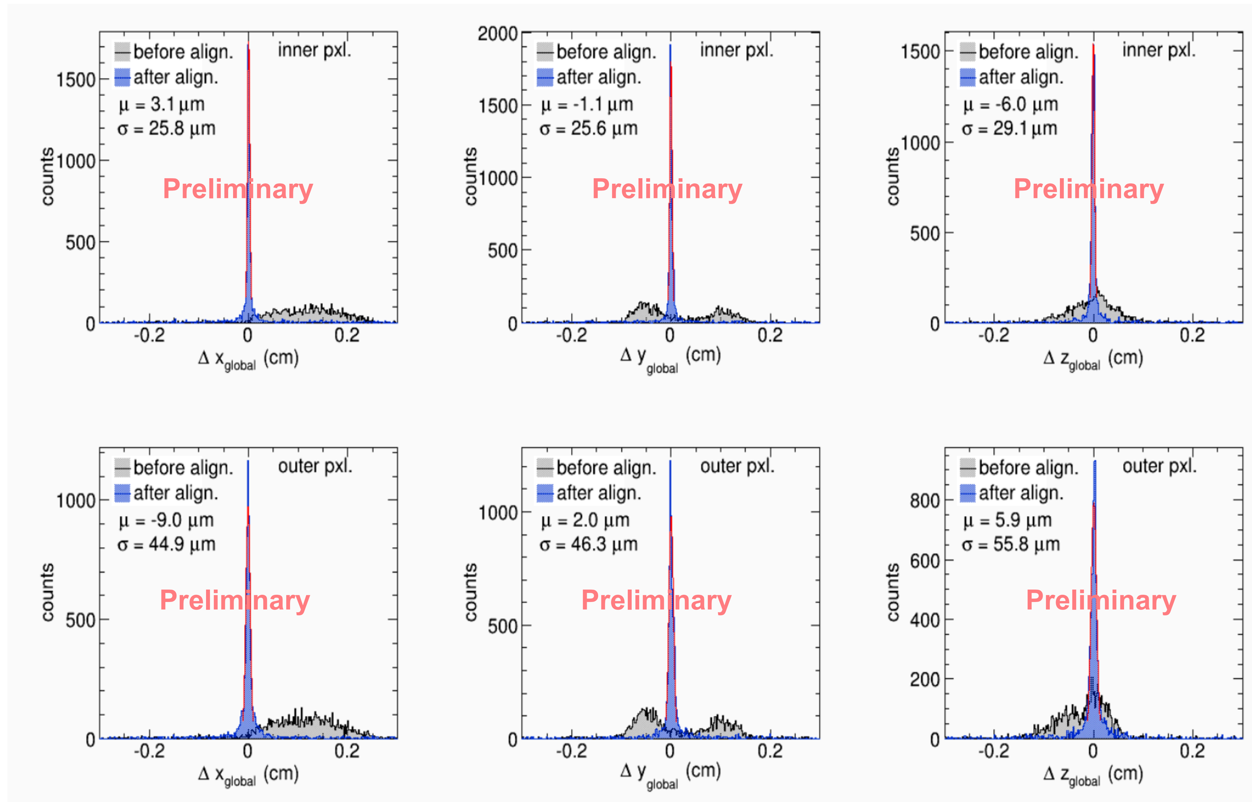


Figure 7: PXL hit residual distributions before and after PXL self-alignment

- Zero magnetic field cosmic obtained at the beginning of the 2014 run were used to self-align the PXL sensors.
- A track formed from two hits on separate layers of a single sector were used to define the tracks and project to opposite side of the detector.
- The PXL sector-to-sector and half-to-half parts were relatively aligned using the observed track-hit residual.
- The method relies on high precision survey data for sensor and ladder placement on sectors.

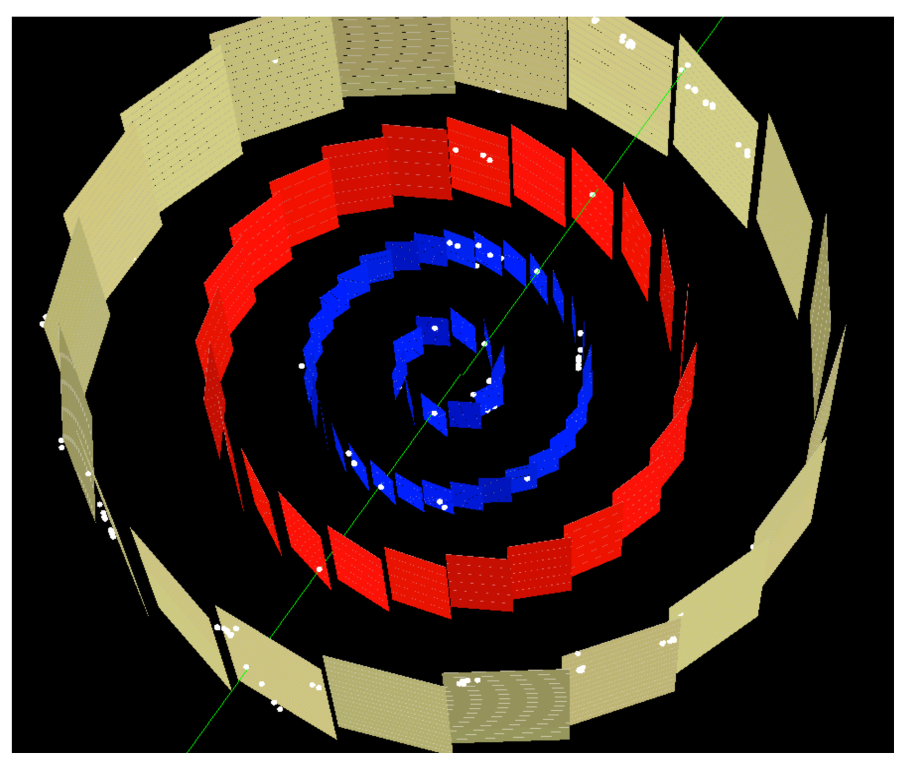


Figure 8: A single cosmic track hits the SSD, the IST and the innermost layers of PXL

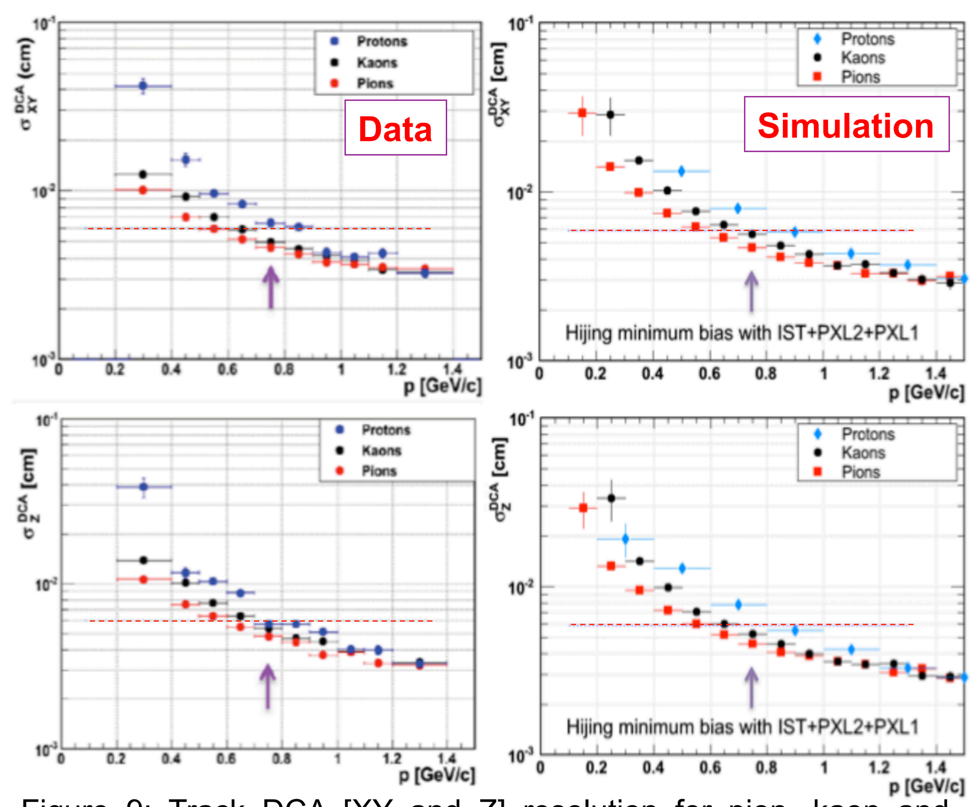


Figure 9: Track DCA [XY and Z] resolution for pion, kaon and proton with HFT for Data [left panels] and Simulation [right panels]. The arrows point at 750 MeV/c values and the horizontal lines show the target values of 60 μm for Kaons.

Summary

- The HFT has been successfully installed and recorded data during the RHIC Run-14 period in 2014.
- Masking is removing noisy sensors/rows/column and / or pixels for a cleaner overall environment.
- In order to take advantage of the intrinsically high resolution of the detector, it is necessary to accurately align the different subassemblies. The achieved alignment is well within our goal of < ~ 20 microns.
- The achieved track pointing resolution in data is below the requirement of 60 μm for p_T = 0.75 Gev/c Kaons.

References

1. STAR Heavy Flavor Tracker Technical Design Report: https://drupal.star.bnl.gov/STAR/starnotes/public/sn0600
2. Z. Lin and M.Gyulassy, phys. Rev. C77 (1996)1222
3. Adamczyk, L. et al. Phys. Rev. Lett. 113 (2014) 142301
4. Lomnitz M: private communication